THE

SURFACE GEOLOGY

OF THE

BASIN OF THE GREAT LAKES

AND THE

VALLEY OF THE MISSISSIPPI.

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On the Surface Geology of the Basin of the Great Lakes, and the Valley of the Mississippi.

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The area bounded on the north by the Eozoic highlands of Canada, on the east by the Adirondacks and Alleghanies, and on the west by the Rocky Mountains, though now, and apparently always, drained by two systems of watercourses, may be properly considered as one topographical district; since much of the water-shed which separates its two river systems is of insignificant height, is composed of unconsolidated "Drift" materials, has shifted its position hundreds of miles, as the water level in the great lakes has varied, and was for a long interval submerged beneath a water connection uniting both drainage systems in one.

In this great hydrographic basin the surface geology presents a series of phenomena of which the details, carefully studied in but few localities, still offer an interesting and almost inexhaustible subject of investigation, but which, as it seems to me, are already sufficiently well known to enable us to write at least the generalities of the history which they record.

The most important facts which the study of the "Drift phenomena" of this region have brought to light are briefly as follows:

1st. In the northern half of this area, down to the parallels of 38°—40°, we find, not everywhere, but in most localities where the nature of the underlying rocks is such as to retain inscriptions made upon them, the upper surface of these rocks planed, furrowed or excavated in a peculiar and striking manner, evidently by the action of one great denuding agent. No one who has seen glaciers and noticed the effect they produce on the rocks over which they move, upon examining good exposures of the markings to which I have referred, will fail to pronounce them the tracks of glaciers.*

Though having a general north-south direction, locally the glacial furrows have very different bearings, conforming in a rude way to the present topography, and following the directions of the great lines of drainage.

On certain uplands, like those of the Wisconsin lead region, no glacial furrows have been observed (Whitney), but on most of the highlands, and in all the lowlands and great valleys, they are distinctly discernible if the underlying rock has retained them.

2d. Some of the valleys and channels which bear the marks of glacial action—evidently formed or modified by ice, and dating from the ice period or an earlier epoch—are excavated far below the present lakes and water-courses which occupy them.

These valleys form a connected system of drainage, at a lower level than the present river system, and lower than could be produced without a continental elevation of several hun-

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* From my own observation on the action of glaciers on rock surfaces in the Alps and in Oregon and Washington Territory, I do not hesitate to assert that no other agent could have produced such effects. A different view is taken of this subject, it is true, but only by those who either have never seen a glacier or have never seen the markings in question. The track of a glacier is as unmistakable as that of a man or a bear.

dred feet. A few examples will suffice to show on what evidence this assertion is based.

Lake Michigan, Lake Huron, Lake Erie, and Lake Ontario are basins excavated in undisturbed sedimentary rocks. Of these, Lake Michigan is 600 feet deep, with a surface level of 578 feet above tides; Lake Huron is 500 feet deep, with a surface level of 574 feet; Lake Erie is 204 feet deep, with a surface level of 565 feet; Lake Ontario is 450 feet deep, with a surface level of 234 feet above the sea.

An old, excavated, now-filled channel connects Lake Erie and Lake Huron. At Detroit the rock surface is 130 feet below the city. In the oil region of Bothwell, &c., from 50 to 200 feet of clay overlie the rock. What the greatest depth of this channel is, is not known.

An excavated trough runs south from Lake Michigan—filled with clay, sand, tree trunks, &c.—penetrated at Bloomington, Ill., to the depth of 230 feet.

The rock bottoms of the troughs of the Mississippi and Missouri, near their junction or below, have never been reached, but they are many feet, perhaps some hundreds, beneath the present stream-beds.

The borings for oil in the valleys of the Western rivers have enabled me not only to demonstrate the existence of deeply buried channels of excavation, but in many cases to map them out. Oil Creek flows from 75 to 100 feet above its old channel, and that channel had sometimes vertical and even overhanging cliffs. The Beaver, at the junction of the Mahoning and Shenango, runs 150 feet above the bottom of its old trough.

The Ohio throughout its entire course runs in a valley which has been cut nowhere less than 150 feet below the present river.

The Cuyahoga enters Lake Erie at Cleveland, more than 100 feet above the rock bottom of its excavated trough. The Chagrin, Vermilion, and other streams running into Lake Erie exhibit the same phenomena, and prove that the surface level of the lake must have once been at least 100 feet lower than now.

The bottom of the excavated channel in which Onondaga Lake is situated, and the Salina salt-wells bored, is at least 414 feet below the surface level of the lake and 50 feet below the sea level. (Geddes. Trans. New York State Agricultural Society, 1859.)

The old channel of the Genesee River at Portage, described by Prof. Hall in the Geology of the 4th District of New York; the trough of the Hudson, traceable on the sea bottom nearly 100 miles from the present river mouth; the deeply buried bed of the Lower Mississippi, are additional examples of the same kind; while the depth to which the Golden Gate, the Straits of Carquinez, the channel of the lower Columbia, the Canal de Haro, Hood's Canal, Puget Sound, &c., have been excavated, indicates a similar (perhaps simultaneous) elevation and erosion of the Western coast of America.

The falls of the Ohio—formed by a rocky barrier across the stream—though at first sight seeming to disprove the theory of a deep continuous channel in our Western rivers, really afford no argument against it, for here, as in many other instances, the present river does not follow accurately the line of the old channel below, but runs along one or the other side of it. In the case of the Louisville falls the Ohio runs across a rocky point which projects into the old valley from the north side, while the deep channel passes under the lowland on the south side, on part of which the city of Louisville is built.

The importance of a knowledge of these old channels in the improvement of the navigation of our larger rivers is obvious, and it is possible it would have led to the adoption of other means than a rock canal for passing the Louisville falls, had it been possessed by those concerned in this enterprise.

I ventured to predict to Gen. Warren that an old filled-up channel would be found passing around the Mississippi rapids, and his examinations have confirmed the prophecy. I will venture still further, and predict the discovery of buried channels of communication between Lake Superior and Lake Michigan—probably somewhere near and east of the Grand Sable—at least, between the Pictured Rocks and the St. Mary's River—between Lake Erie and Lake Ontario through Canada,—between Lake Ontario * and the Hudson by the valley of the Mohawk,—between Lake Michigan and the Mississippi, somewhere along the line I have before indicated. I also regard it probable that a channel may be found connecting the upper and lower portions of the Tennessee River, passing around the Mussel Shoals. This locality lies outside of the area where the Northern Drift deposits were laid down to fill and conceal ancient channels, but the excavation and the filling up of the channel of the Tennessee—like that of the Ohio—were determined by the relative altitude of the waters of the Gulf. The channel of the Lower Tennessee must have been excavated when the southern portion of the Mississippi valley was higher above the Gulf level than now, and Prof. Hilgard has shown that at a subsequent period, probably during the Champlain epoch, the Gulf coast was depressed 500 feet below its present relative level. This depression must have made the Lower Mississippi an arm of the sea, by which the flow of the Ohio and Tennessee was arrested, their channels filled, terraces formed, &c. If the Upper Tennessee has, as appears, a channel

* When the water in the lake basin had subsided to near its present level, its old avenues of escape being all silted up by the Drift clays and sands, the surplus made its exit by the line of lowest levels wherever that chanced to run. As that happened to lie over the rocky point that projected from the northern extremity of the Alleghanies into the lake basin, there the line of drainage was established in what is now known as Niagara river.

Though among the most recent of the events recorded in our surface geology, this choice of the Niagara outlet by the lake waters was made so long ago that all the erosion of the gorge below the falls has been accomplished since. The excavation of the basin into which the Niagara flows—the basin of Lake Ontario, of which Queenstown Heights form part of the margin—belongs to an epoch long anterior.

lower than the Mussel Shoals, it must be somewhere connected with the deep channel of the lower river.

It should be said, however, that it by no means follows that where an old earth-filled channel passes around the rocky barrier by which the navigation of our rivers is impeded, it will be most convenient and economical to follow it in making a canal to pass the obstacle, as the course of the old channel may be so long and circuitous that a short rock cutting is cheaper and better. The question is, however, of sufficient importance to deserve investigation, before millions of dollars are expended in rock excavation.

If it is true that our great lakes can be connected with each other and with the ocean, both by the Hudson and Mississippi, by ship canals,—in making which no elevated summits nor rock barriers need be cut through,—the future commerce created by the great population and immense resources of the basin of the great lakes may require their construction.

3d. Upon the glacial surface we find a series of unconsolidated materials generally stratified, called the "Drift deposits."

Of these, the first and lowest are blue and red clays (the Erie clays of Sir Wm. Logan), generally regularly stratified in thin layers, and containing no fossils, but drifted coniferous wood and leaves. Over the southern and eastern part of the lake basin, these clays contain no boulders, but towards the North and West they include scattered stones, often of large size; while in places beds of boulders and gravel are found resting directly on the glacial surface.

In Ohio, the Erie clays are blue, nearly 200 feet in thickness, and reach up the hill-sides more than 200 feet above the present surface of Lake Erie. On the shores of Lake Michigan these clays are in part of a red color, showing that they have been derived from different rocks, and they there include great numbers of stones.

On the peninsula between Lake Erie and Lake Huron the Erie clays fill the old channel which formerly connected these lakes, having a thickness of over 200 feet, and containing a few scattered stones.

4th. Above the Erie clays are sands ot variable thickness and less widely spread than the underlying clays. These sands contain beds of gravel, and, near the surface, teeth of elephants have been found, water-worn and rounded.

5th. Upon the stratified clays, sands, and gravel of the Drift deposits are scattered boulders and blocks of all sizes, of granite, greenstone (diorite and dolerite), silicious and mica slates, and various other metamorphic and eruptive rocks, generally traceable to some locality in the Eozoic area north of the lakes. Among these boulders many balls of native copper have been found, which could have come from nowhere else than the copper district of Lake Superior.

Most of these masses are rounded by attrition, but the large blocks of Corniferous limestone which are scattered over the southern margin of the lake basin in Ohio show little marks of wear. These masses, which are often 10 to 20 feet in diameter, have been transported from 100 to 200 miles south-eastward from their places of origin, and deposited sometimes 300 feet above the position they once occupied.

6th. Above all these Drift deposits, and more recent than any of them, are the "lake ridges,"—embankments of sand, gravel, sticks, leaves, &c., which run imperfectly parallel with the present outlines of the lake margins, where highlands lie in the rear of such margins. Of these, the lowest on the South shore of Lake Erie is a little less than 100 feet above the present lake level; the highest, some 250 feet. In New York, Canada, Michigan, and on Lake Superior, a similar series of ridges has been discovered, and they have everywhere been accepted as evidence that the waters of the lakes once reached the points which they mark. That they are nothing else than ancient lake beaches we shall hope to prove farther on.

In the southern half of the Mississippi valley the evidences of glacial action are entirely wanting, and there is nothing corresponding to the wide-spread Drift deposits of the north. We there find, however, proofs of erosion on a stupendous scale, such as the valley of East Tennessee, which has been formed by the washing out of all the broken strata between the ridges of the Alleghanies and the massive tables of the Cumberland Mountains,—the cañons of the Tennessee, 1,600 feet deep, &c. Here also, as in the lake basin, the channels of excavation pass far below the deep and quiet waters of the lower rivers; proving by their depth that they must have been cut when the fall of these rivers was much greater than now.

The history which I derive from the facts cited above is briefly this:

1st.—That in a period probably synchronous with the glacial epoch of Europe,—at least corresponding to it in the sequence of events,—the northern half of the continent of North America had a climate comparable with that of Greenland; so cold, that wherever there was a copious precipitation of moisture from oceanic evaporation, that moisture was congealed and formed glaciers which flowed by various routes toward the sea.

2nd.—That the courses of these ancient glaciers corresponded in a general way with the present channels of drainage. The direction of the glacial furrows proves that one of these ice rivers flowed from Lake Huron, along a channel now filled with drift, and known to be at least 150 feet deep, into Lake Erie, which was then not a lake, but an excavated valley into which the streams of Northern Ohio flowed, 100 feet or more below the present lake level. Following the line of the major axis of Lake Erie to near its eastern extremity, here turning north-east, this glacier passed through some channel on the Canadian side, now filled up, into Lake Ontario, and thence found its way to the sea either by the St. Lawrence or by the Mohawk and Hudson. Another glacier occupied the bed of Lake Michigan, having an outlet southward through a channel—now concealed by the heavy beds of drift which occupy the surface about the south end of the lake—

passing near Bloomington, Ill., and by some route yet unknown reaching the trough of the Mississippi, which was then much deeper than at present.

3RD.—At this period the continent must have been several hundred feet higher than now, as is proved by the deeply excavated channels of the Columbia, Golden Gate, Mississippi, Hudson, &c., which could never have been cut by the streams that now occupy them, unless flowing with greater rapidity and at a lower level than they now do.

The depth of the trough of the Hudson is not known, but it is plainly a channel of erosion, now submerged and become an arm of the sea. As has been before stated, this channel is marked on the sea bottom for a long distance from the coast, and far beyond a point where the present river could exert any erosive action, and hence it is a record of a period when the Atlantic coast was several hundred feet higher than now.

The lower Mississippi bears unmistakable evidence of being —if one may be permitted the parodox—a half-drowned river ; that is, its old channel is deeply submerged and silted up, so that the "father of waters," lifted above the walls that formerly restrained him, now wanders lawless and ungovernable whither he will in the broad valley.

The thickness of the delta deposits at New Orleans is variously reported from 1500 feet upwards, the discrepancies being due to the difficulty of distinguishing the alluvial clays from those of the underlying Cretaceous and Tertiary formations. It is certain, however, that the bottom of the ancient channel of the Mississippi has never been reached between New Orleans and Cairo; the instances cited by Humphreys and Abbot in their splendid study of this river being but repetitions of the phenomena exhibited at the falls of the Ohio—the river running over *one side* of its ancient bed.

The trough of the Mississippi is not due to synclinal structure in the underlying rocks, but is a valley of erosion simply. Ever since the elevation of the Alleghanies—*i.e.*, the close of the Carboniferous period—it has been traversed by a river which drained the area from which flow the upper Mississippi, the Ohio, the Tennessee, &c. Since the Miocene period, the Missouri, Arkansas, and Red rivers have made their contributions to the flood that flowed through it. The depth to which this channel is cut in the rock proves that at times the river must have flowed at a lower level and with a more rapid current than now; while the Tertiary beds formed as high as Iowa and Indiana in this trough, and the more modern Drift clays and boulders which partially fill the old rock cuttings, show that the mouth and delta of the river have, in the alternations of continental elevation, travelled up and down the trough at least a thousand miles; and that not only is it true, as asserted by Ellet, that every mile between Cairo and New Orleans once held the river's mouth, but that in the several advances and recessions of the waters of the Gulf the mouth has been more than twice at each point. The change of place of the delta has been caused, however, for the most part, by oscillations of the sea level, and not, as Ellet supposed, by the filling of the channel by the materials transported by the river itself.

Drift Deposits.

The Drift deposits which cover the glacial surface, consisting of fine clays below, sands and gravel above, large transported boulders on the surface, and the series of lake ridges (beaches) over all, form a sequence of phenomena of which the history is easily read.

Erie Clays.

The lower series of blue or red clays—the "Erie clays" of Sir William Logan—over a very large area, rest directly on the planed and polished rock-surfaces. These clays are often accurately stratified, were apparently deposited in deep and generally quiet water, and mark a period when the glacial ice-masses, melted by a change of climate, retreated northward, leaving large bodies of cold, fresh water* about their southern margins, in which the mud produced by their grinding action on the paleozoic rocks of the Lake District was first suspended and then deposited.

On the shores of Lake Erie these clays contain no boulders, and very few pebbles, while farther North and West boulders are more abundant. This is precisely what might be expected from the known action of glacial masses on the surfaces over which they pass. Their legitimate work is to grind to powder the rock on which they rest; an effect largely due to the sand which gathers under them, acting as emery on a lead wheel. The water flowing from beneath glaciers is always milky and turbid from this cause. Rocks and boulders are sometimes frozen into glaciers, and thus transported by them, but nearly all the boulders carried along by a glacier are such as have fallen from above; and a moraine can hardly be formed by a glacier except when there are cliffs and pinnacles along its course.

In a nearly level country, composed of sedimentary rocks passed over by a glacier, we should have very little débris produced by it, except the mud flour which it grinds.

The Erie clays would necessarily receive any gravel or stones which had been frozen into the ice, either as scattered pebbles or stones, distributed to some distance from the glacial mass by floating fragments of ice, or as masses of frozen gravel, or larger and more numerous boulders near the glacier. In some localities torrents would pour from the sides and from beneath the glacier, so that here coarse material would alone resist the rapid motion of the water, and the stratification of the sediments would be more or less confused.

In regard to the *cause* of the gradual amelioration of the climate of the glacial epoch, by which the great glaciers of the

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* *Cold*, because coming from the melting glacier, and depositing with its sediments no evidences of life; *fresh*, because no marine shells are found in it—only drift-wood—while the equivalent "Champlain" clays on the coast are full of marine Arctic shells.

lake basin were driven northward and finally altogether dissolved, we are not left entirely to conjecture.

Cosmical causes possibly and probably had the chief agency in producing this result, but we have unmistakable evidence of at least the co-operation of another and perhaps no less potent cause, viz., continental depression.

If a cosmical cause had simply increased the annual temperature till the glaciers were all melted, without the action of any other agent, we should never have had the accumulation of drift deposits which now occupy all the glacial area; but the drainage streams, changed in all their courses from ice to water, would have flowed freely and rapidly away through their deeply cut channels to deposit their abundant sediments only where their transporting power was arrested, in the depths of the ocean.

Instead of this, we everywhere find evidence that this flow was checked, and a basin of quiet water formed by an advance of the ocean consequent upon a subsidence of the land. On the Atlantic and Gulf coasts this depression progressed until the sea-level was more than 500 feet higher than now. The effect of this depression was to deeply submerge the eastern margin of the continent, and cover it with the "Champlain" clays.

It is evident that at this period the drainage from the great water-shed of the continent must have been met by the quiet waters of the ocean almost at the sources of the present draining streams, and as the "dead water" gradually crept up the valleys, arresting the transporting power of their currents, their old channels would be silted up and obliterated, and their valleys partially filled with materials for their subsequent terraces. In the advance and subsequent recession of the line of "dead water" we have ample cause for all our terrace phenomena.

This continental depression accounts satisfactorily for the filling of the old channels of the Mississippi and the Ohio, as a depression of 500 feet would bring the ocean nearly to Pittsburgh on the Ohio, to St. Paul on the Mississippi.

But I think we have evidence that the continent did not sink uniformly in all its parts, but *most at the North.* Not to cite any other proof of this,—northern coast fiords, &c.—the altitude of the loess-like deposits of the upper Mississippi and Missouri (the lacustrine non-glacial sediments of this period of submergence), the upward reach of the Drift clays of the lake basin, the filling of the valleys of the streams flowing into the Ohio and Lake Erie, the old lake beaches marking the former water-level in the lake basin—all indicate that the continental subsidence was greatest towards the north. To this subsidence we must, as I think, attribute the accumulation of water in the lake basin and Mississippi valley to form the great inland sea of fresh water, of which traces everywhere abound. It seems to me scarcely necessary to suppose any other barriers by which this sea was enclosed than the highlands that encircle it—such as are roughly outlined by the light tint on Prof. Guyot's map of North America—and the sea-water which filled the mouths of the two* straits by which it communicated with the ocean.

Yellow Sands and Surface Boulders.

I have mentioned that on the Erie clays are beds of gravel, sand and clay, and over these again great numbers of transported boulders, often of large size and of northern and remote origin.

These surface deposits have been frequently referred to as the direct and normal product of glacial action, the materials torn up and scraped off by the great ice ploughs in their long journeys from the North; in fact, as some sort of huge termi-

* If there *were* two. That there was one in the course of the Mississippi we know, and that so long that, though salt at one end, it must have been fresh at the other.
The eastern outlet of the lake waters may not have been by the St. Lawrence, but as likely through the gap between the Adirondacks and the Alleghanies. The shallow channels between the Thousand Islands, and the Lachine Rapids seem to indicate that the St. Lawrence is a comparatively *new* line of drainage for the lakes.

nal and lateral moraines. I have, however, disproved, as I think, this theory of their transportation in a paper published some years since (Notes on the Surface Geology of the Basin of the Great Lakes. Proc. Bost. Nat. Hist. Soc. 1863), in which it is urged that the continuous sheet of the Erie clays upon which they rest, and which forms an unbroken belt between them and their place of origin, precludes the idea that they have been transported by any ice-current or rush of water moving over the glacial surface; as either of these must have torn up and scattered the soft clays below.

There is, indeed, no other conclusion deducible from the facts than that these sands, gravels, granite and greenstone boulders—masses of native copper, &c., which compose the superficial Drift deposits—have been *floated* to their resting places, and that the floating agent has been ice, in the form of *icebergs;* in short, that these materials have been transported and scattered over the bottom and along the south shore of our ancient inland sea just as similar materials are now being scattered over the banks and shores of Newfoundland.

If we restore in imagination this inland sea, which we have proved once filled the basin of the lakes, gradually displacing the retreating glaciers, we are inevitably led to a time in the history of this region when the southern shore of this sea was formed by the highlands of Ohio, &c., the northern shore a wall of ice resting on the hills of crystalline and trappean rocks, about Lake Superior and Lake Huron.

From this ice-wall masses must from time to time have been detached,—just as they are now detached from the Humboldt Glacier,—and floated off southward with the current, bearing in their grasp sand, gravel and boulders—whatever composed the beach from which they sailed. Five hundred miles south they grounded upon the southern shore; the highlands of now Western New York, Pennsylvania and Ohio, or the shallows of the prairie region of Indiana, Illinois and Iowa; there melting away and depositing their entire loads—as I have sometimes seen them, a thousand or more boulders on a few acres, resting on the Erie clays and looking in the distance like flocks of sheep—or dropping here and there a stone and floating on east or west, till wholly dissipated.

These boulders include representatives of nearly all the rocks of the Lake Superior country, conspicuous among which are granites with rose-colored orthoclase, gray gneiss, and diorites, all characteristic of the Laurentian series; hornblendic rocks, massive or schistose, and dark greenish or bluish silicious slates, probably from the Huronian; dolorites and masses of native copper apparently from the Keweenaw Point copper region.

In the Drift gravels I have found pebbles and small boulders of nearly all the paleozoic rocks of the lake basin, containing their characteristic fossils, viz.: The Calciferous Sand-rock with *Maclurea*, Trenton and Hudson with *Ambonychia radiata*, *Cyrtolites ornatus*, Medina with *Pleurotomaria litorea*, Corniferous with *Conocardium trigonale*, *Atrypa reticularis*, *Favosites polymorpha*, Hamilton with *Spirifer mucronatus*, &c.

The granite boulders are often of large size, sometimes six feet and more in diameter, and generally rounded.

The largest transported blocks I have seen are the more or less angular masses of corniferous limestone mentioned on a preceding page.

Along the southern margin of the Drift area, especially on the slopes of the highlands of Northern Ohio, the Drift sands and gravels are of considerable thickness, forming hills of 100 feet, or more, in height, generally stratified, but often without any visible arrangement. These deposits are very unevenly distributed, with a rolling surface frequently forming local basins, which hold the little lakelets or sphagnous marshes so characteristic of the region referred to. These are the beds to which I have alluded as constituting, in the opinion of some geologists, a great glacial moraine, but from the fact that they are locally stratified, and overlie the older blue clays, I have regarded them as transported, not by glaciers but by icebergs.

Possibly some part of this Drift material may have accumulated along the margin of the great glacier, moved by its agency; but in that case we should expect to find in it abundant fragments of the rocks which outcrop in the region under consideration, whereas I have rarely, if ever, seen in these Drift gravels any representatives of the rocks underlying the South margin of the lake basin.

By whatever agency transported, the Drift gravels have, like the boulders, for the most part come from some remote point at the North, and were once spread broadcast along the southern shore of the inland iceberg-bearing sea.

In the retreat of the shore line during the contraction of the water surface down to its present area, every part of the slope of the southern shore between the present water surface and the highest lake level of former times, *i. e*, all within a vertical height of 300 feet or more, must in turn have been submitted to the action of the shore waves, rain and rivers, by which if, as is probable, the retrograde movement of the water line was slow, these loose materials would be rolled, ground, sorted, sifted and shifted, so that comparatively little would be left in its original bedding; the fine materials, clay and sand, would be washed out and carried further and still further into the lake basin, and spread over the bottom, to form, in short, the upper sandy layers of the Drift.

At certain points in its descent, the water level seems to have been for a time stationary, and such points are marked by terraces and the long lines of ancient beaches which have been referred to. A similar "lake ridge" now borders the south shore of Lake Michigan, where it may be observed in the process of formation; and this seems to be the legitimate effect of waves everywhere on a sloping shore composed of loose material; storms driving up sand and gravel to form a ridge which ultimately acts as a barrier to the waves that built it. Winds, also, often assist in building up, and sometimes alone form these ridges, by transporting inland the beach sand.

In other localities, where hard rock masses formed the shore of our inland sea, perpendicular wave-worn cliffs were produced; and many of these now stand as enduring and indisputable monuments of a sea whose waves, perhaps, for ages beat against them. Such cliffs may be observed on Little Mountain, in Lake county, in the valley of the Cuyahoga, in Medina and Lorain county, Ohio, along the outcrops of the Carboniferous conglomerate and Waverly sandstone.

In all the changes through which the valley of the Mississippi passed during the "Drift Period," its general structure and main topographical features remained the same. Yet the character of its surface suffered very important modifications, and such as deeply affected its fitness for human occupation.

As we have seen, the glacial epoch was marked by erosion on a grand scale.

Then, our river valleys and some of our lakes—though mapped out long before—were excavated to a much greater depth than they now have.

During their subsequent submergence, these valleys and lakes were partially or perfectly filled with the drift deposits which covered all the surface, like a deep fall of snow, rounded its outlines and softened all its asperities.

When the waters were withdrawn, the rivers again began clearing their obstructed channels; a work not yet accomplished, and in many instances not half done. Numbers of the old channels were wholly filled and obliterated, and the streams that once traversed them were compelled to find quarters elsewhere. Examples of this kind have been already cited, and they could be multiplied indefinitely.

ORIGIN OF THE GREAT LAKES.

The question of the origin of our lakes is one that requires more observation and study than have yet been given to it before we can be said to have solved all the problems it involves. There are, however, certain facts connected with the structure of the lake basins, and some deductions from these facts, which may be regarded as steps already taken toward the full understanding of the subject. These facts and deductions are briefly as follows:

1st. Lake Superior lies in a synclinal trough, and its mode of formation therefore hardly admits of question, though its sides are deeply scored with ice-marks, and its form and area may have been somewhat modified by this agent.

2d. Lake Huron, Lake Michigan, Lake Erie, and Lake Ontario, are excavated basins wrought out of once continuous sheets of sedimentary strata, by a mechanical agent, and that ice or water, or both.

That they have been filled with ice, and that this ice formed great moving glaciers, we may consider proved. The west end of Lake Erie may be said to be carved out of the Corniferous limestone by ice action; as its bottom and sides and islands—horizontal, vertical, and even overhanging surfaces—are all furrowed by glacial grooves, which are parallel with the major axis of the lake.

All our great lakes are probably very ancient, as since the close of the Devonian period the area they occupy has never been submerged beneath the ocean, and their formation may have begun during the Coal Measure epoch.

The Laurentian belt, which stretches from Labrador to the Lake of the Woods, and thence northward to the Arctic Sea, forms the oldest known portion of the earth's surface. The shores of this ancient continent, then high and mountainous, were washed by the Silurian sea, where the débris of the land was deposited in strata that subsequently rose to the surface, and formed a broad low margin to the central mountain belt, just as the Cretaceous and Tertiary strata flank the Alleghanies in the Southern States.

In the lapse of countless ages, all the mountain peaks and chains of the Laurentian continent have been removed and carried into the sea, and this has been done by rivers of water and rivers of ice. That these mountains once existed there can be no reasonable doubt, for their truncated bases remain as witnesses, and it is scarcely less certain that glaciers have flowed down their slopes of sufficient magnitude and reach to deeply score the plain which encircled them.

It will be noticed that all the great lakes of the continent hold certain relations to the curving belt of Laurentian highlands.

Some of them are embraced in the foldings of the Eozoic rocks, and fill synclinal troughs; but most of the series, from Great Bear Lake to Lake Ontario, exhibit the same geological and physical structure, are basins of excavation in the paleozoic plain that flanks in a parallel belt the Laurentian area. Few of us have any conception of the enormous general and local erosion which that plain has suffered. Those who will take the trouble to examine the section across Lake Ontario, from the Alleghanies to the Laurentian hills of Canada, and compare it with the other sections in the Lake Winnepeg district, radial to the Laurentian arch, given by Mr. Hind in his report on the Assinniboin country, will be sure to find the comparison interesting and suggestive; suggestive especially of a community of structure and history, and of an inseparable connection between the lake phenomena and the topographical features of the Laurentian highlands, flanked by the paleozoic plain.

In estimating the influences that might have affected the number and magnitude of glaciers on the sides of the Laurentian mountains, it should not be forgotten that the Cretaceous sea swept the western shore of the Paleozoic and Laurentian continent, from the Gulf of Mexico to the Arctic Ocean; and whether we consider this sea as a broad expanse of water simply dotted with islands, or a strait traversed by a tropical current, we have in either case conditions peculiarly favorable to the formation of great glacial masses of ice, *i. e.*, a broad evaporating surface of warm water swept by westerly winds that carried all suspended moisture immediately on to a mountain belt, which served as a sufficient condenser.

This, at least, may be positively asserted in regard to the agency of ice in the excavation of the lake basins, that their bottoms and sides, wherever exposed to observation, if composed of resistant materials, bear indisputable evidence of ice action, proving that these basins were filled by moving glaciers in the last ice period, if never before, and that part, at least, of the erosion, by which they were formed, is due to these glaciers..

No other agent than glacial ice, as it seems to me, is capable of excavating broad, deep, boat-shaped basins, like those which hold our lakes.

If the elevation of temperature and retreat northward of the glaciers of the lake basins were not uniform and continuous, but alternated with periods of repose, we should find these periods marked by excavated basins, each of which would serve to measure the reach of the glacier at the time of its formation, the lowest basin being the oldest, the others formed in succession afterwards. Such a cause would be sufficient to account for any local expansions of the troughs of the old ice rivers.

Where glaciers flow down from highlands on to a plain, or into the sea, the excavating action of the ice mass must terminate somewhat abruptly in the formation of a basin-like cavity, beyond which would be a rim of rock, with whatever of débris the glacier has brought down to form a terminal moraine.

When glaciers reach the sea, the great weight of the ice mass must plough up the sea bottom out to the point where the greater gravity of water lifts the ice from its bed, and bears it away as an iceberg.

If it is true, as the facts I have cited indicate, that our lakes are but portions of great excavated channels locally filled with drift material, the fiords of the northern Atlantic and Pacific coast present remarkable parallels to them; and I would suggest Puget's Sound, Hood's Canal, and other portions of that wonderful system of navigable channels about Vancouver's Island, as affording interesting and instructive subjects for comparison. Like our lakes their channels are for the most part excavated from sedimentary strata which form a low and comparatively level margin to the bases of mountain chains and peaks. They too have their depths and shallows, their basins and bars, and probably all who have seen them will assent to Prof. Dana's view, that they are the "result of subærial excavation," in which glaciers performed an important part.

THE "LOESS" OF THE MISSISSIPPI VALLEY.

The "Bluff formation" of the West, sometimes called "Loess," from its resemblance to the Loess of the Rhine, I have on a preceding page designated as a lacustrine, non-glacial Drift deposit. It seems to be the sediment precipitated from the waters of our great inland sea in its shallow and more quiet portions, to which icebergs, with their gravel and boulders, had no access, and where the glacial mud was represented only by an impalpable powder, which mingled with the wash of the adjacent land, land shells, &c.

It is evidently one of the most recent of the deposits which come into the series of Drift phenomena, and was apparently thrown down while the broad water surface which once stretched over the region where it is found was narrowing by drainage and evaporation, till, by its total disappearance, this sheet of calcareous mud was left.

It underlies much of the prairie region, and once filled, often to the brim, the troughs of the Mississippi and Missouri, so deeply excavated during the glacial epoch. When the system of drainage was re-established the new rivers began the excavation of their ancient valleys in the Loess. When they had cut into or through this stratum, so that it stood up in escarpments on either side, man came and called it the *Bluff* formation, because it composed or capped the bold bluffs of the river banks. It is often, however, only a facing to the rocky cliffs, which are the true walls of these valleys, and which are monuments of an age long anterior to the date of its deposition.